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April 25, 2022

The Role of Hydrogen in Wyoming's Energy Economy

Presented to the Joint Minerals, Business & Economic Development Committee

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Wyoming Energy Strategy

Primary Objective

EMPOWERING OUR NATION WITH AN
ALL-OF-THE-ABOVE NET-ZERO ENERGY MIX

Strategic Opportunities

Energy Heritage

- CCUS deployment + decarbonized products
- Hydrogen + H_2 products
- Demand creation

Electrification

- Storage, transmission & resiliency
- Value-added electricity
- Retail evolution
- Repurposed Infrastructure

Energy Evolution

- Advanced nuclear tech
- REE and CM
- Carbon engineering
- Non-linear value chains

Initiatives and areas of focus

- Hydrogen
- Sequestration
- Advanced Nuclear
- REE & CM

Why Hydrogen?

- ***Co-fire with, or convert thermal generation to, H*** → *Reduced emissions*
- ***Coal to H*** → *sustainability path for this heritage resource*
- ***Nat. Gas. to H*** → *preserve and enhance access to markets*
- ***Renewable energy to H*** → *value add opportunity, additional transmission options, grid resilience*
- ***Integrate with other low-carbon energy sources and carbon management system*** → *advanced manufacturing, zero emissions petrochemicals, value added opportunities …*
- *Other: heavy transport alternative fuel, industrial heat….*

Hydrogen production

2 primary methods to produce H*

Thermal (Reforming, Gasification, Pyrolysis…)

Hydrocarbon or other organic molecule (NG, Coal, Waste, biomass…)

Carbon Capture

Electrochemical (Electrolysis)

Zero-emissions energy (Renewable or Nuclear)

Water molecule

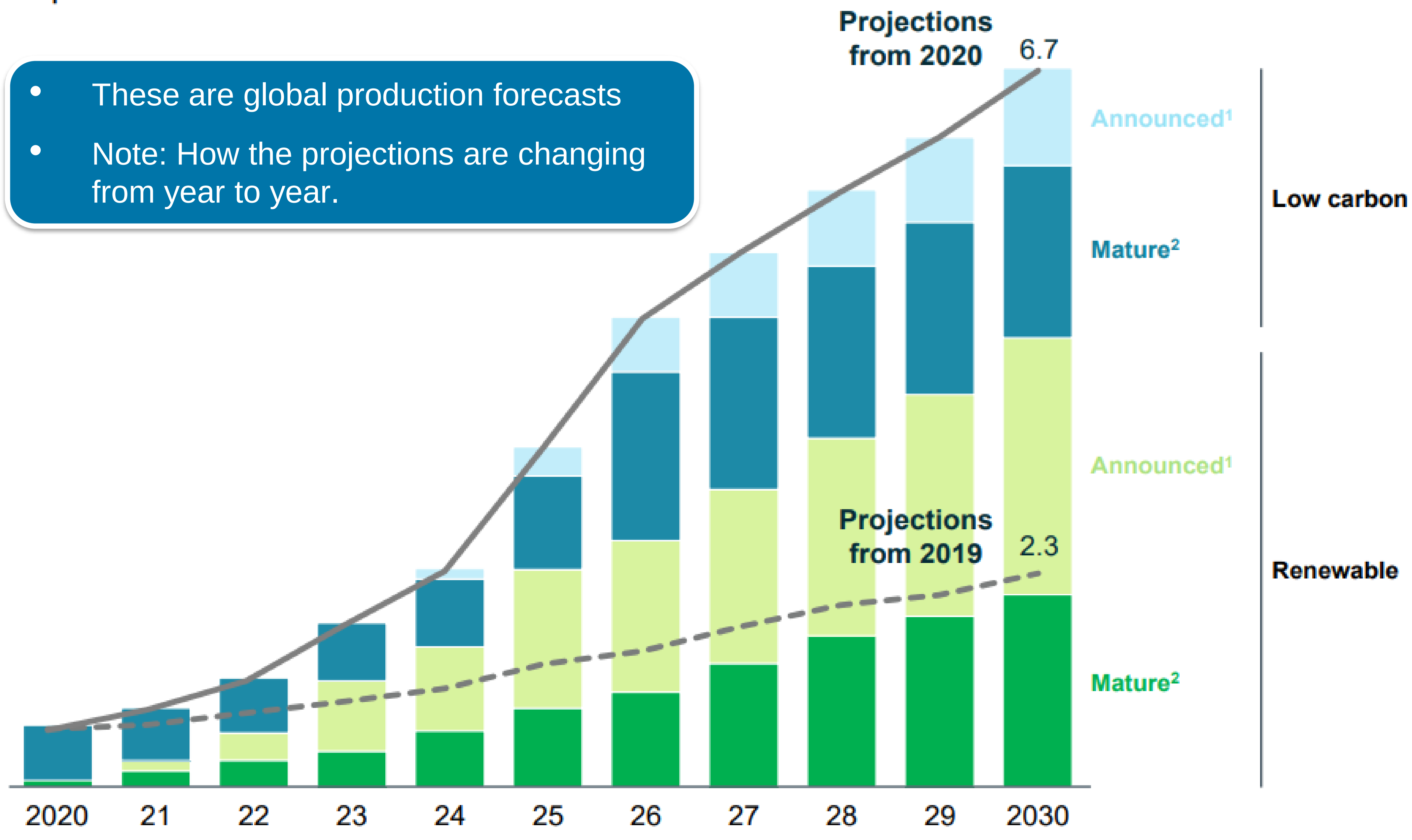
Hydrogen, with low, net-zero or negative CI

- Historically, colors have been used to describe different methods (e.g. blue, green, pink,….)
- This has gone out of favor as people now tend to talk about the Carbon Intensity (CI) of the method without referencing feedstock
- Important to note:
  - Both methods produce low CI hydrogen
  - Both methods consume water

*one can also produce hydrogen through fermentation

Projected Production

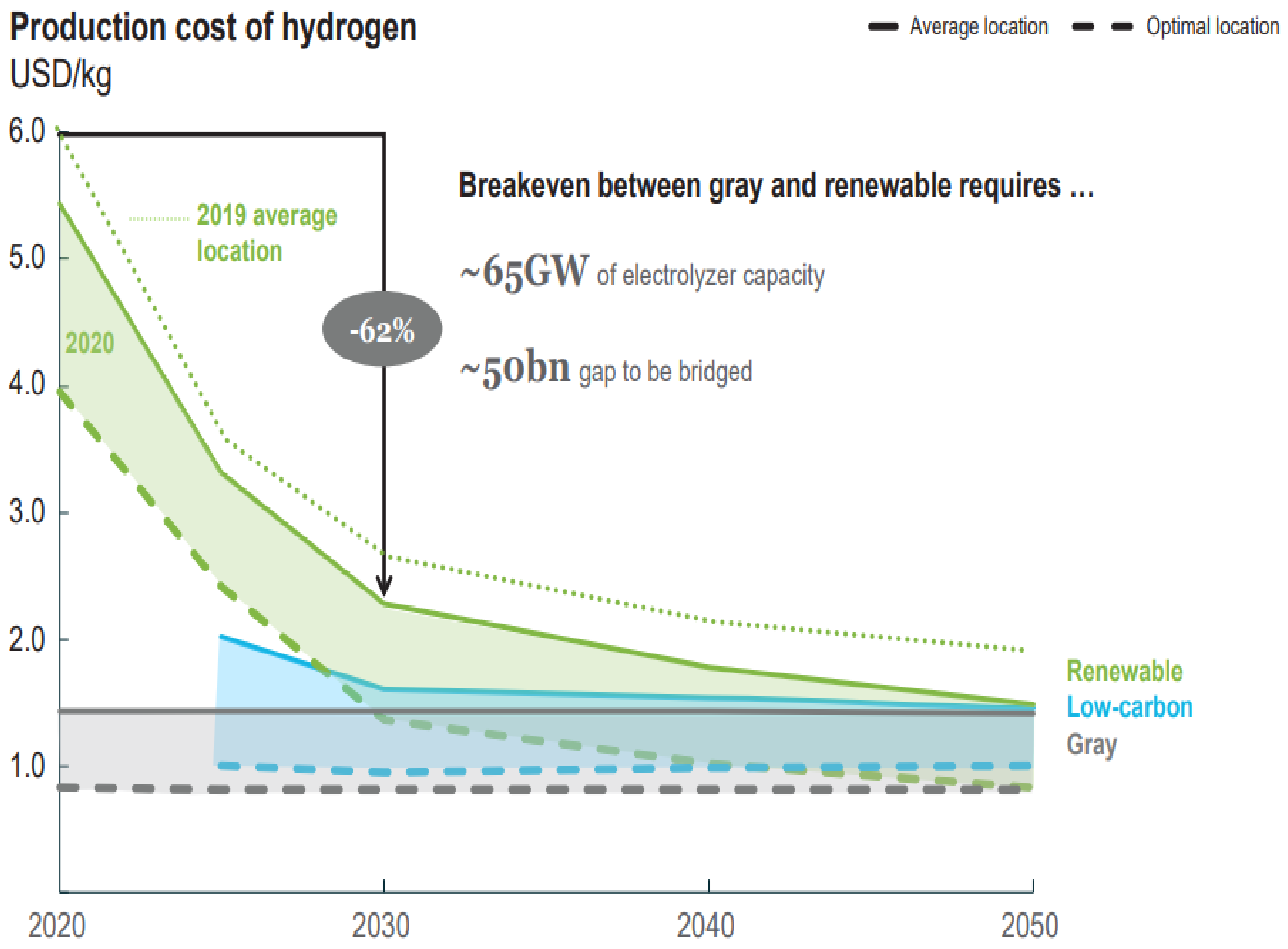
Exhibit 5: Announced clean hydrogen capacity through 2030



- These are global production forecasts
- Note: How the projections are changing from year to year.

1. Includes projects at preliminary studies or at press announcement stage
2. Includes projects that are at the feasibility study or front-end engineering and design stage or where a final investment decision (FID) has been taken, under construction, commissioned or operational

Exhibit 6: Hydrogen production costs by production pathway



Renewable hydrogen
- Dedicated renewable/electrolyzer system
- Fully flexible production
- Scale up of renewable hydrogen production
- Additional costs to reach end supply price

Low-carbon hydrogen
- Development of CO_2 pipelines and at-scale sites
- Scale-up of low-carbon hydrogen production
- Scale-up of CCS outside of hydrogen production

Key assumptions
- Gas price 2.6–6.8 USD/Mmbtu
- LCOE USD/MWh 25–73 (2020), 13–37 (2030) and 7–25 (2050)

Source: The Hydrogen Council 2021
https://hydrogencouncil.com/wp-content/uploads/2021/02/Hydrogen-Insights-2021-Report.pdf
Mt = million tons

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Hydrogen Status in Wyoming

Public Sector

- UW SER – Cent. of Excellence
- UW SER – Public Outreach
- UW SER – DOE Award
- WEA - Integration into WES
- WEA – H RFP
- WEA – Coal to H RFP
- WEA/SER/Gov's Office - WISHH
- WEA/SER – Student Innovation Prize
- WEA/LEADS/SER – H Status and Roadmap

Private Sector

- Williams Companies
- Tallgrass Energy
- North Shore Energy
- Black Hills Energy
- Anschutz/PCOW
- Nordex Acciona
- 8 Rivers

Wyoming Strengths and Weakness

Strengths

- Feedstock diversity and abundance
- Geographic location
- Associated infrastructure
- CO_2 mgmt. infrastructure (incl. policy)

Weaknesses

- Water
- Storage(?)
- Geographic location(?)
- Demand pull

The WISHH partnership addresses several of these weaknesses.

Western Inter-State Hydrogen Hub (WISHH)

- *CO – UT – WY – NM*
- *Agreement to pursue a Hydrogen Hub under the Infrastructure Investment and Jobs Act (IIJA)*
  - *Exclusivity clause - member states will submit one application collectively and will not support any others*
  - *Expansion clause – additional states may join if member states all agree*
- *IIJA hydrogen program*
  - *$8B for development of at least 4 hydrogen infrastructure hubs*
  - *Places importance on feedstock diversity, value chain completeness and EEEJ* considerations*
- *Coalition greatly strengthens the hub concept in the region*
- *Several positive unforeseen consequences already*
- *Potential for collaborative efforts in other areas*

*EEEJ = Equity, Environment and Energy Justice

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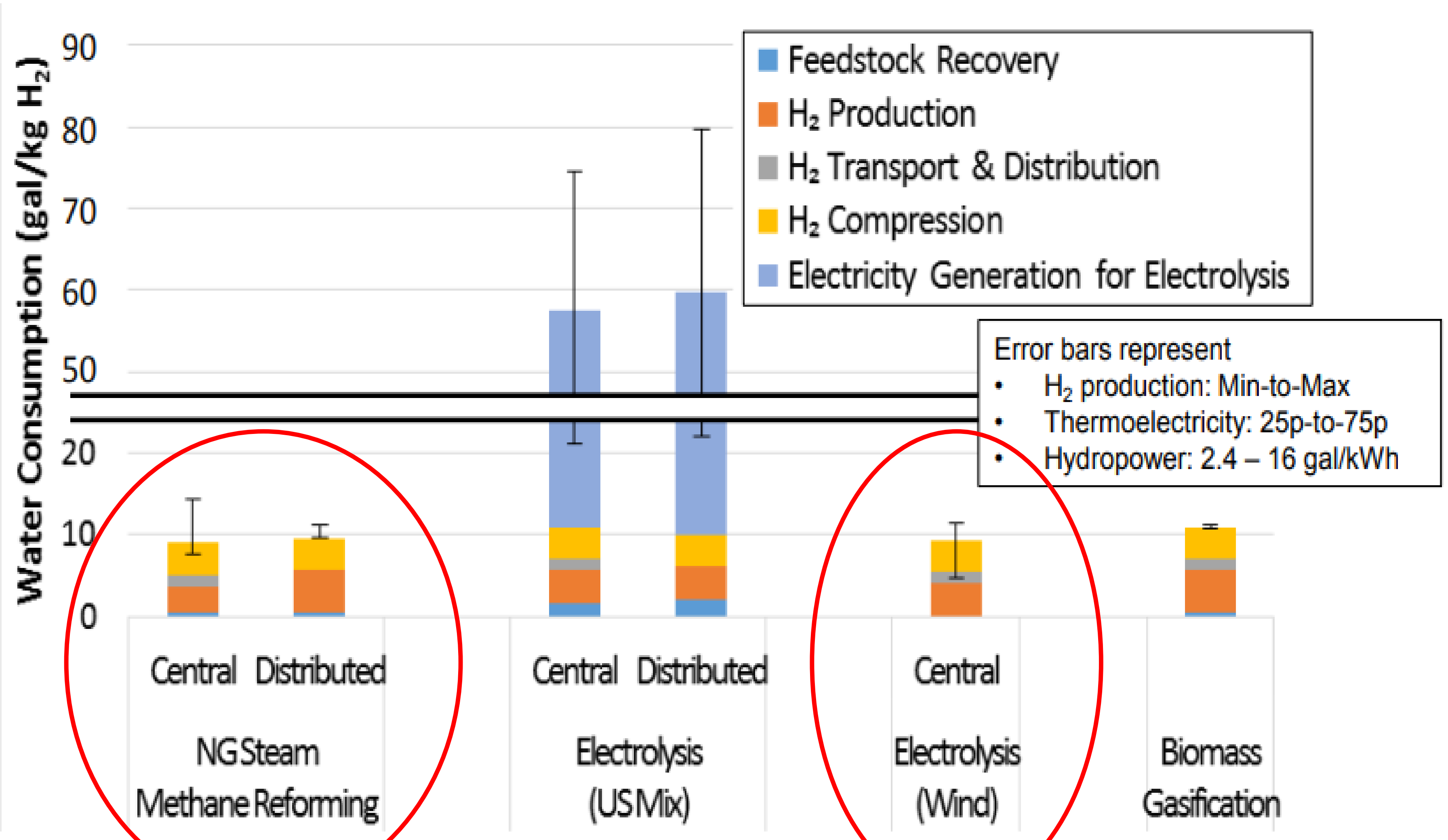
IIJA Hydrogen Hub RFI needs list

The DOE published a Request For Information that detailed some of the expected characteristics of a successful hub application:

•Ability to meet or exceed the **clean hydrogen production standard** developed under Section 822(a)
•Ability to create and sustain jobs, particularly high paying **union jobs**, and support long-term jobs for local residents
•Ability to **employ workers currently employed in the fossil industry** or those that may no longer have jobs as a result of the clean energy transition, in regions where applicable
•Capacity to demonstrate the **complete value chain** at scale for production, processing, delivery, storage, and end-use of clean hydrogen
•Ability to drive **sustained regional specific economic growth**, including through demonstrated connections to the **value chain** at scale for production, processing, delivery, storage, and end-use of clean hydrogen
•Potential for the proposed H2Hub to be **developed into a national clean hydrogen network** to facilitate a clean hydrogen economy, including potential for replicability
•Quantification of **decarbonization potential** compared to alternate pathways
•Quantification of criteria pollutant **emission reductions**, compared to alternate pathways
•Project financial model and analysis including total project cost with **revenue potential** and pathway to **private sector investment** and **commercial sustainability** beyond the DOE funding
•**EEEJ strategy**, including significant and meaningful community engagement plans, connection to hubs and post-hub benefit, to ensure EEEJ goals are achieved
•**Cost, quantity, and purity** of hydrogen produced/demanded
•Potential for **U.S. manufacturing** of components/equipment across the hydrogen supply chain
•**Reliability, availability, capacity** of clean energy source(s)
•**Availability of necessary hydrogen infrastructure** including storage of hydrogen, energy feedstocks, and/or permanently sequestered CO2, where applicable
•Commitment (or at least identification) of **specific off-taker agreements** (e.g., power purchase agreements)
•Creation of clear **workforce education and training pathways**, including registered apprenticeships, into high quality jobs (including union jobs)
•Effective use of **regional resources/markets**
•**Market analysis** that includes current and future supplier/off-take potential
•Plan to ensure **environmental impacts** such as **water use**, impact on DACs or adjacent regions, etc., are minimized
•Complete list of project partners with letters of commitment or MOUs
•Formal partnership with and support from relevant **local labor unions**, where applicable
•Potential for **longevity and sustainability** after DOE FOA funding ceases

Water Use

Life-cycle water consumption of hydrogen production varies by feedstock source and conversion process – Accomplishment



✓ WCF for electricity strongly impacts water consumption for H_2 production via electrolysis and compression at refueling stations

✓ H_2 production and compression are the largest water consumers in the fuel's life cycle

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- The 2 most significant hydrogen production methods in WY (SMR and Wind-Electrolysis) consume roughly the same amount of water - ~5 gallons/kg or 120 bbls/ton (excluding transport and compression, or conversion to other H products such as NH_4)
- Projected global hydrogen production in 2030 is 6.7 million tons per year (~800 million bbls of water per year).
- Projected US hydrogen production in 2030 is 1.4 million tons per year (~165 million bbls of water per year).
- Projects in Wy range from 3-200+ tons/day, which would equate to 400 and 24 000 bbls of water per day.
- Important caveat no.1: surprisingly difficult to find robust data on this.
- Important caveat no.2: Life Cycle Analysis is notoriously sensitive to scenario definition, boundary conditions, and input assumptions.
- A lot of work to be done here….

Life-Cycle Analysis of Water Consumption for Hydrogen Production. Amgad Elgowainy (PI), Jeongwoo Han (presenter), Uisung Lee, Jeff Li, Jennifer Dunn, and Michael Wang. Argonne National Laboratory. June 8, 2016.
chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/viewer.html?pdfurl=https%3A%2F%2Fwww.hydrogen.energy.gov%2Fpdfs%2Freview16%2Fsa039_elgowainy_2016_o.pdf&clen=1242054&chunk=true

General Policy Directions

and examples from across the US

Market standardization

- A carbon intensity framework is a technology neutral approach to assess the Green House Gases (GHGs) associated with hydrogen production. It opens up competition between various hydrogen production routes that meet the required carbon intensity at least costs
- A carbon intensity framework can use a well-to-gate life cycle assessment (LCA) to rigorously account for GHGs arising both at the site of production and upstream of production

Technological mandates

- Establish near and long-term storage targets for clean electrolytic hydrogen at the gigawatt-scale to achieve cost competitiveness.
- Set hydrogen pipeline injection targets and regulation to drive affordable decarbonization and long duration storage solutions
- Direct gas utilities to develop decarbonization and reliability plans to address transitioning to clean hydrogen where feasible, safe, and cost-effective.

Support schemes

- Establish electricity rates that allow utilities to recover the cost, including T&D and demand charges, for the creation of hydrogen through electrolysis
- Create a state-level investment tax credit, production tax credit, or incentives for clean hydrogen production, transportation or storage
- Include clean hydrogen in Renewable Portfolio Standards and/or Renewable Gas Standards

Market creation

- Establish an emissions certification and tracking framework
- Clarify jurisdictional authority for interstate hydrogen pipelines
- Reduce barriers to development through state specific efforts to harmonize local requirements, streamlining of permitting processes and environmental impact reports

Policy Considerations* for Wyoming

A framework for evaluation and recognition of hydrogen that meets a certain Carbon Intensity criteria.

- This could simply be recognition of a federal, or market state, standard
- Could follow a time-based 'ramp'.
- Important for preserving access to markets – consider potential for Low-carbon fuel standards to be adopted in various markets.

A framework for long-term utility planning

- Other states are working on policy that ensures that hydrogen is built in to the long term planning
- Does HB200 have consideration of conversion to H? or co-firing with H?

Cost-centric incentives

- Preferred rates for ***production*** of H (https://www.mytpu.org/tacoma-power-announces-the-nations-first-electrofuel-tariff/)
- Preferred rates for ***use*** of H in industrial processes (https://app.bchydro.com/accounts-billing/rates-energy-use/electricity-rates/electrification-rates.html)
- Could this approach be applied to WY's severance/production taxes? And recovered indirectly through economic activity?

Demand creation

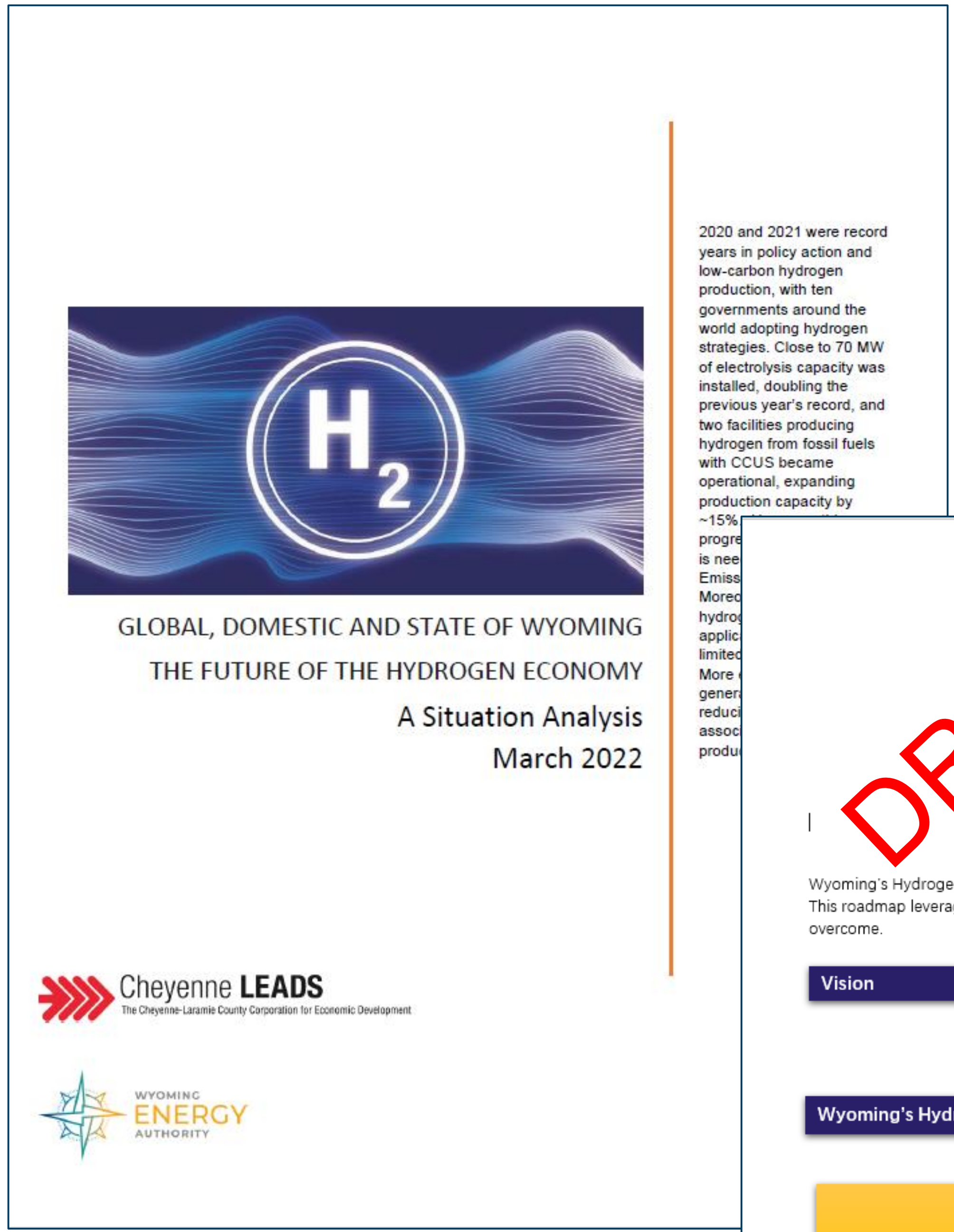
- A lot of vehicle fleets in, and passing through, WY. Could the state facilitate deployment of fueling distribution systems?

Sub-surface storage

- Wyoming will likely need to develop storage in depleted O&G fields, or maybe even in aquifers.
- Does WY (or FERC) pore-space ownership, unitization, well permitting statutes (et.al.,) consider injection, storage and withdrawal of H?

*As a member of the executive it is inappropriate for me to lobby or go on the record as for or against any policy options.

Coming up…



2020 and 2021 were record years in policy action and low-carbon hydrogen production, with ten governments around the world adopting hydrogen strategies. Close to 70 MW of electrolysis capacity was installed, doubling the previous year's record, and two facilities producing hydrogen from fossil fuels with CCUS became operational, expanding production capacity by ~15%

GLOBAL, DOMESTIC AND STATE OF WYOMING

THE FUTURE OF THE HYDROGEN ECONOMY

A Situation Analysis

March 2022

DRAFT

DRAFT

Roadmap to Build a Hydrogen Economy: 2022-2026

Wyoming's Hydrogen Roadmap provides a course of action with specific roles and responsibilities for the various stakeholders over the next five years: 2022-2026. This roadmap leverages the combined strengths of these stakeholders to deliver on our vision while simultaneously addressing the challenges that must be overcome.

Vision

Wyoming is the Energy State with an all-of-the-above energy strategy and leads the region in the low-carbon hydrogen economy.

Wyoming's Hydrogen Roadmap: Strategic Priorities

Strategic Hydrogen Priorities

1. Develop resources, utilizing all feedstock options, for a robust, decarbonized production ecosystem.
2. Invest in the development of core and adjacent infrastructure including transportation, storage, and carbon management.
3. Identify and develop end use options and evolving markets both within and outside of Wyoming.
4. Develop supportive policy and regulatory framework for the advancement of hydrogen as an energy source.
5. Develop workforce and community infrastructure.

The roadmap is a multi-dimensional strategy which leverages the opportunities and addresses the challenges as Wyoming plays a major role in for the domestic and global low-carbon hydrogen economy.

- **Continued work with Cheyenne LEADS to finalize Situational Report and high-level Hydrogen Roadmap**
- **Next Frontier Energy Summit May 11 & 12, in Cheyenne**
- **Next Frontier Energy Action Team – industry consortium to advise, direct and execute on Wyoming Energy Strategy opportunities and initiatives (incl. hydrogen, CCUS, advanced reactors, REE…)**
- **IIJA Hydrogen Hub Program – Funding Opportunity Announcement released before May 15, application due late summer(?)**

Stay Connected

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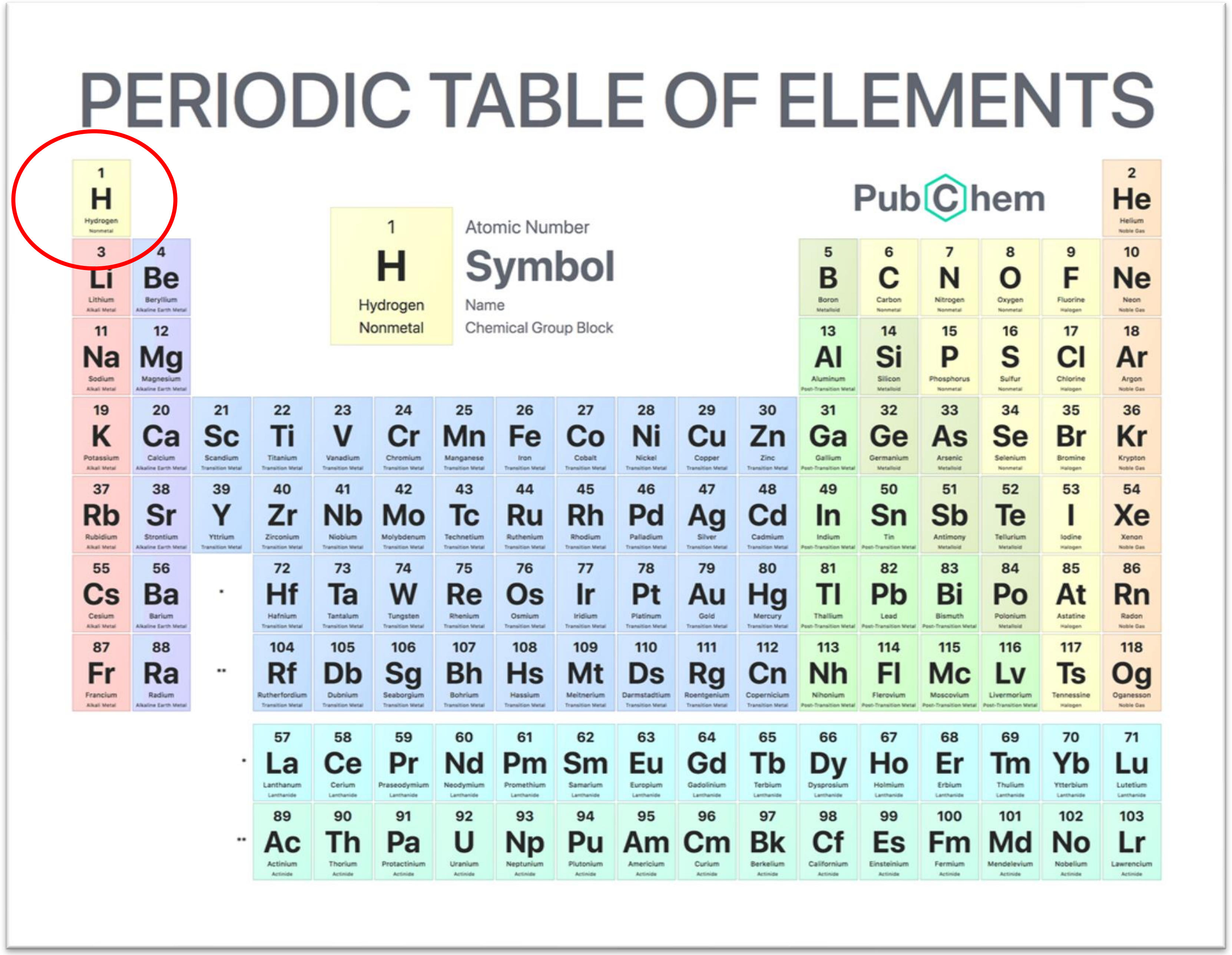
What is Hydrogen?

- Most abundant element
- Rarely exists in isolation. Typically in bonded relationship with other elements (e.g. H_2O, hydrocarbons)
- Gas vs liquid
- Can be a fuel
  - Rockets, fuel cells, etc.
- **no carbon dioxide (CO_2)



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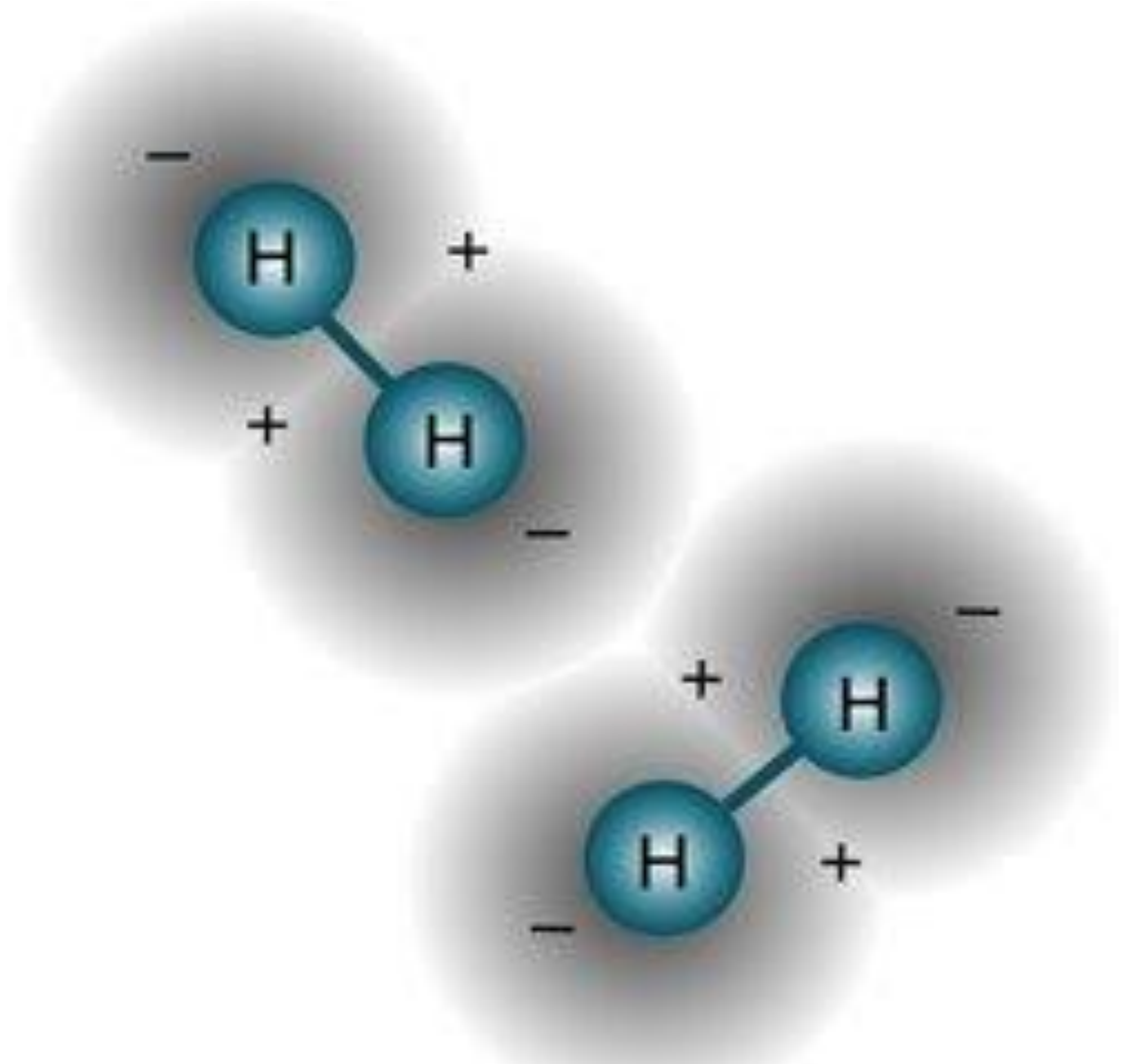
Ways to Make Hydrogen

- Electrolysis (H_2O)
- Natural Gas (CH_4)
  - Steam Methane Reforming
    - H_2 and <u>CO_2 byproduct</u>
  - Pyrolysis
    - Decomposition of methane
    - H_2 and solid carbon (C)



Storing Hydrogen

- Gas vs liquid
  - Gas = high pressure tanks
  - Liquid = −252.8°C (-423°F)
- Convert it to ammonia (NH_3)
  - Fertilizer, energy production, chemical feedstock
  - Liquid = -33°C (-28°F)
- Liquid organic hydrogen carriers
- Can be a way of storing energy

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Transporting Hydrogen

°F)

- Truck, train, pipelines
- Pipeline
  - Pure
  - Blended
  - Convert to ammonia

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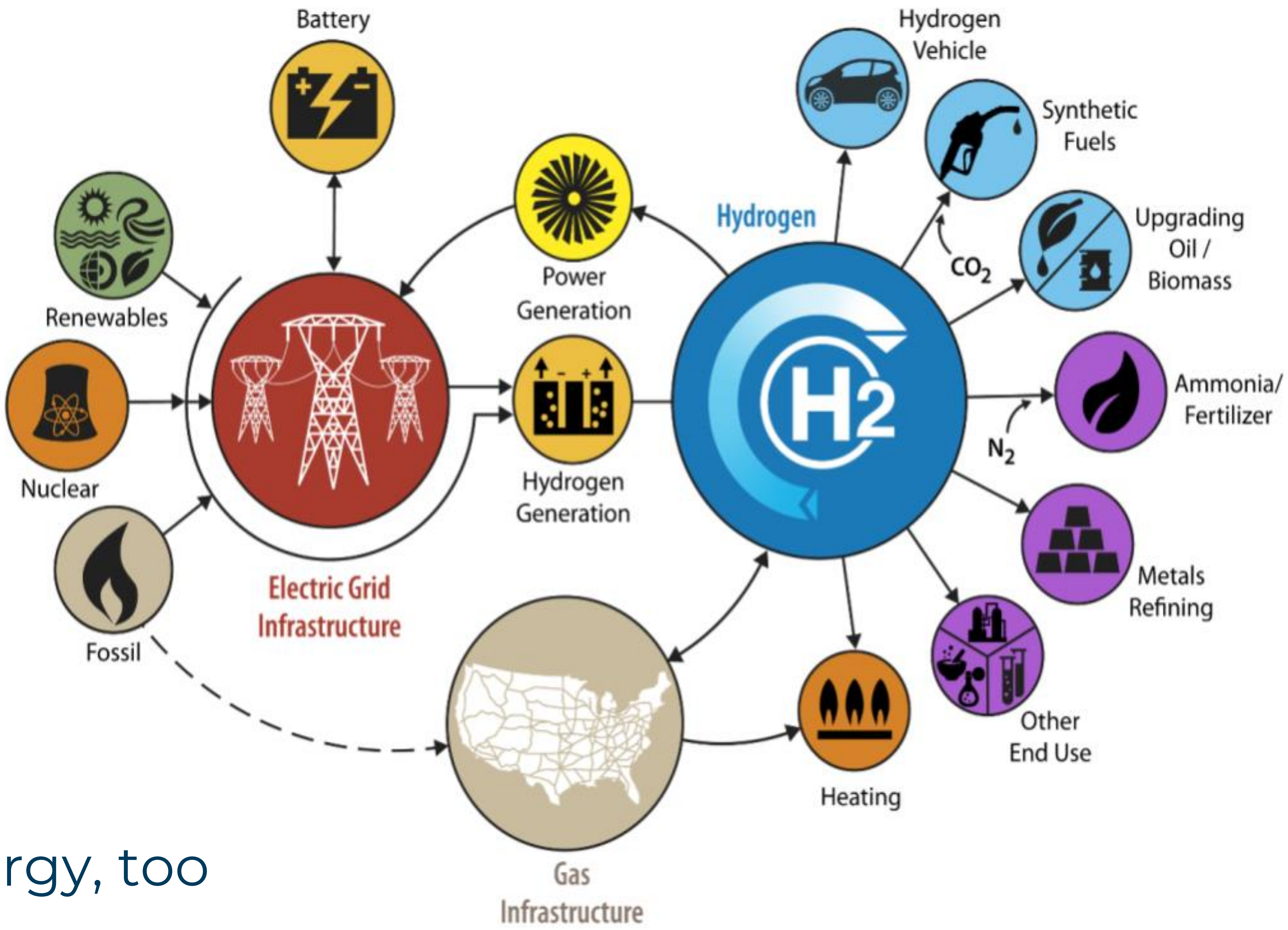
Hydrogen End Use / Markets



*Storing backup energy, too